Wideband Low Profile Double Inverted-F Antenna for 5.2/5.8 GHz WLAN and 5.5 GHz WiMAX Applications

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***Abstract*—Wideband low profile double Inverted-F antenna (DIFA) for 5.2/5.8 GHz WLAN and 5.5 GHz WiMAX applications by means of numerical simulation is presented. The antenna has compact size of 9×20 mm^2 and provides a wide bandwidth of 2.1 GHz (4675 MHz~6775 MHz) which covers the 5.2/5.8 GHz WLAN and 5.5 GHz WiMAX applications. Moreover it has very high peak gain and lower gain variation within the 10 dB return loss bandwidth. The VSWR of DIFA varies from 1.0412 to 1.1960 within the antenna return loss bandwidth. Also the antenna provides peak return loss of -39.0732, -21.6220 and -21.7404 dB at 5.2, 5.5 and 5.8 GHz respectively.**

***Index Terms*— Inverted-F antenna (IFA), Double IFA (DIFA), Low profile antenna, WLAN, WiMAX.**

I. Introduction

In recent times, the rapid development in wireless communication system leads to several growing demands with the designing of various portable devices require small, low profile and multi-function antenna. In order to satisfy these demands, Inverted-F Antenna (IFA) has been widely used in portable devices due to its compact, low profile configuration, ease of fabrication and favorable electrical performance. At present the demand of wireless local area networks (WLANs) are increasing numerously worldwide, because they provide high speed connectivity and easy access to networks without wiring also in recent times of worldwide interoperability for microwave access (WiMAX), which can provide a long operating range with a high data rate for mobile broadband wireless access, faultless internet access for wireless users becomes more popular [1-3]. The rapid growing WLAN operating bands are IEEE 802.11 b/a/g at 2.4 GHz (2400–2484 MHz), 5.2 GHz (5150–5350 MHz) and 5.8 GHz (5725–5825 MHz) also the bands of WiMAX operation in the 2.5 GHz band (2500–2690 MHz), 3.5 GHz band (3300–3700 MHz) and 5.5 GHz band (5250–5850 MHz) [4–5]. To provide the increasing demand and cover up the widespread applications of 5.2/5.8 GHz WLAN and 5.5 GHz WiMAX a low profile antenna with wider bandwidth is desirable.

A compact monopole antenna for dual industrial, scientific and medical (ISM) band (2.4 and 5.8 GHz) operation [1], a novel composite monopole antenna for 2.4/5.2/5.8 GHz WLAN and 2.5/3.5/5 GHz WiMAX operation in a laptop computer [2], a tri-band planar inverted-F antenna (PIFA) for 2.4/5.2 GHz WLAN and 5.75 GHz WiMAX applications [3], a CPW-fed triangle-shaped monopole antenna for 2.4/5 GHz WLAN and 3.4 GHz WiMAX applications [4], a printed monopole antenna with a trapezoid conductor-backed plane for 2.4/5.2/5.8 GHz WLAN bands and 2.5/3.5/5.5 GHz WiMAX operation [5], a capacitively fed hybrid monopole/slot chip antenna for 2.5/3.5/5.5 GHz WiMAX operation in the mobile phone [6], a printed antenna with a quasi-self-complementary structure for 5.2/5.8 GHz WLAN operation [7], a novel broadband dual-frequency spider-shaped dipole antenna for 2.4/5.2 GHz WLAN [8], a novel dual-broadband T-shaped monopole antenna with dual shorted L-shaped strip-sleeves for 2.4/5.8 GHz WLAN operation [9], a very small size planar two-strip monopole printed on a thin (0.4 mm) FR4 substrate for 2.4/5.2/5.8 GHz triple-band WLAN operation in the laptop computer [10], a broadband low-profile printed T-shaped monopole antenna for 5 GHz WLAN application [11], printed double-T monopole antenna for 2.4/5.2 GHz Dual-band WLAN operations [12] and a planar CPW-fed slot antenna on thin substrate for dual-band operation of WLAN applications [13] have been proposed.

In this article, we present a promising antenna with low profile named double inverted-F antenna (DIFA) for 5.2/5.8 GHz WLAN and 5.5 GHz WiMAX applications.

II. Antenna Design

In designing the wideband low profile antenna for 5.2/5.8 GHz WLAN and 5.5 GHz WiMAX applications, we examine the possibility of increasing antenna bandwidth, gain and maintaining the input impedance near about 50 &! throughout the application bands with simplifying its structure. Using method of moments (MoM's) in Numerical Electromagnetic Code (NEC) [14], we conducted parameter studies to ascertain the effect of different loading on the antenna performance to find out the optimal design where optimum segmentation of each geometrical parameter are used. The antenna is assumed to feed by 50 &! coaxial connector. In our analysis we assume the copper conductor

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and the antenna was intended to be matched to 50 &! system impedance. Figure 1 represents the basic geometry of the IFA. Here one leg of IFA directly connected to the feeding and another leg spaced *s* from the ground plane. For the simulation we consider printed circuit board (PCB) with permittivity of å$_r$=2.2, substrate thickness of 1.58 mm and the dimensions of the ground plane considered as 60 × 60 mm^2.

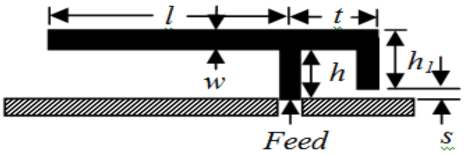


Figure 1. Inverted-F Antenna (IFA).

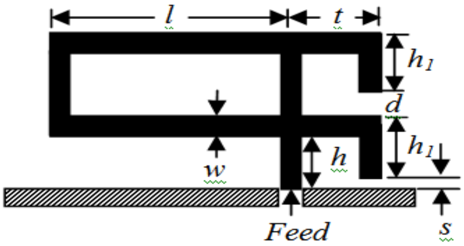


Figure 2. Double Inverted-F Antenna (DIFA).

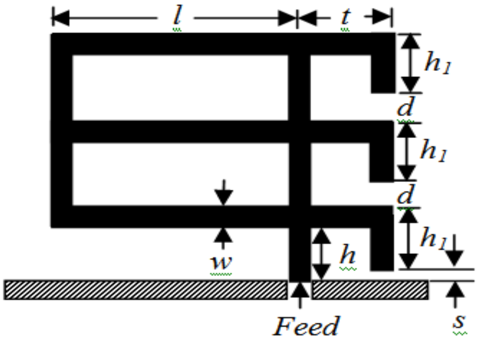


Figure 3. Triple Inverted-F Antenna (TIFA).

Figure 2 represents the modified IFA where a load equal to the IFA is applied to the horizontal strip by shorting the end terminals titled as double IFA (DIFA). Figure 3 represents the modified IFA where load equal to the IFA is applied to the horizontal strip of DIFA by shorting the end terminals is titled as triple IFA (TIFA). For IFA of Figure 1, the resonant frequency related to *w* given as [15]

$$f_1 = c/4(l+t+h_1) \tag{1}$$

Where *c* is the speed of light. The effective length of the current is $l+t+h_1+w$. Under this case the resonant condition can be expressed as

$$l+t+h_1+w=\lambda_0/4 \tag{2}$$

The other resonant frequency that is a part of linear combination with the case $0<w<(l+t)$ and is expressed as

$$f_2 = c/4(l+t+h_1-w) \tag{3}$$

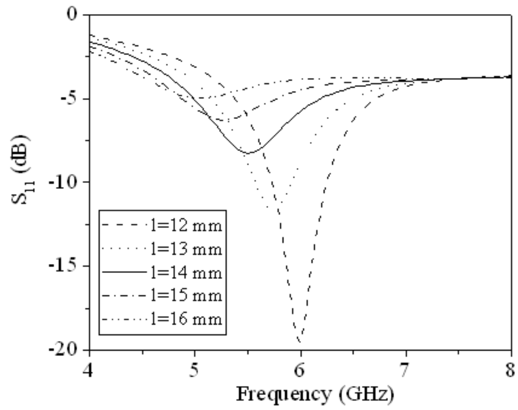


Figure 4. Effects of length *l* on the return loss as a function of frequency on the antenna structure of Figure 1.

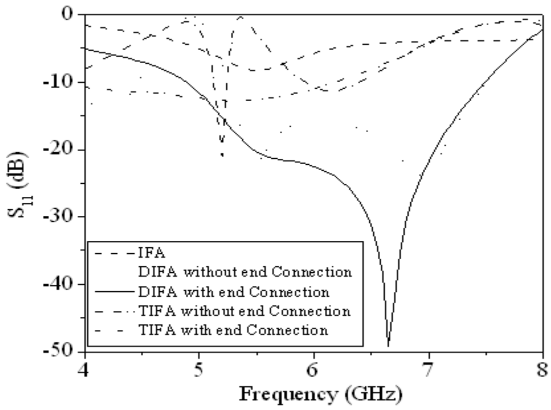


Figure 5. Return loss as a function of frequency for different types of antennas.

The resonant frequency (f_r) is a linear combination of resonant frequency associated with the limiting case. For the antenna geometry of Figure 1, f_r can be written from equation (1) and (2) as [16]

$$f_r = r.f_1 + (1-r)f_2 \tag{4}$$

Where $r=w/(l+t)$. With the help of resonant frequency theory of IFA and impedance matching concept, we consider the dimension of the IFA as *l=13 mm, t=5 mm,* h_1*=3 mm, h=4 mm, s=1 mm* and *w=4 mm.* Figure 4 shows the effects of length *l* on the return loss as a function of frequency on the IFA of Figure 1. From the simulated results when *l=14 mm, t=5 mm, h=4 mm,* h_1*=3 mm, w=4 mm* and *s=1 mm* the variation of return loss with frequency is like covering the whole 5 GHz operating band (frequency ranges 5150 – 5850 MHz) band but the return loss stay above the required 10 dB level.

When a load equal to the IFA is applied on the horizontal strip of IFA then the performance of the return loss improves slightly. But when we connect both the ends of the loaded IFA, the antenna structure of Figure 2 titled as double IFA (DIFA) the performance of return loss improves appreciably. When we apply load again on the horizontal strip of DIFA titled triple IFA (TIFA) as shown in Figure 3 then the performance of the antenna decrease extensively. The return loss variation of different types of antenna structure is shown in Figure 5.

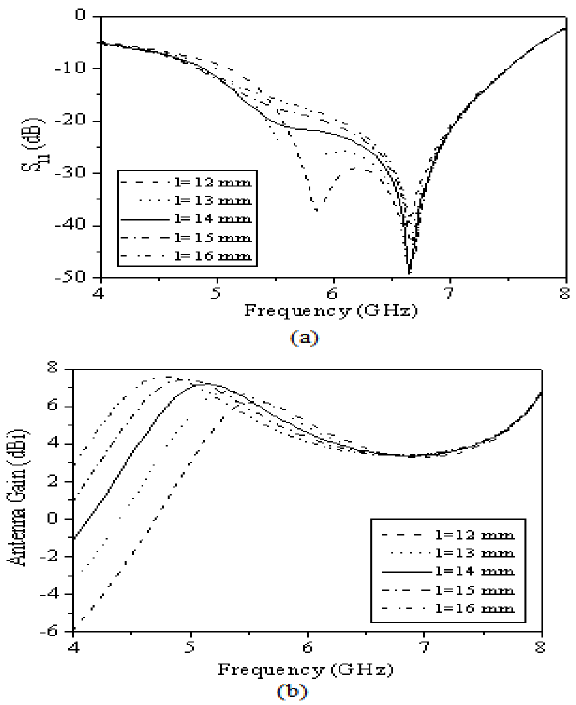


Figure 6. (a) Return loss and (b) gain as a function of frequency with the different length *l* of the antenna structure of Figure 2.

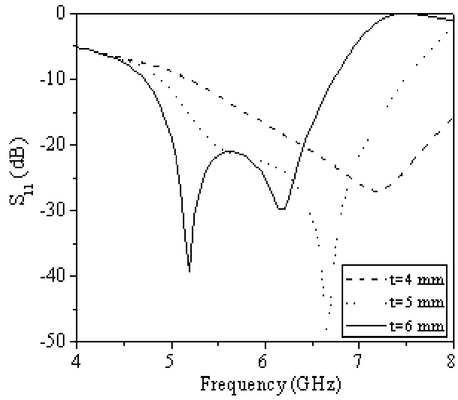


Figure 7. Return loss as a function of frequency with the different tap distance *t* of the DIFA of Figure 2 when *l=14 mm*.

Figure 6 (a) and (b) shows the effects of *l* on the return loss and gain of DIFA respectively, when *w=4 mm*, *t=5 mm*, *h=4 mm*, h_1*=3 mm*, *s=1 mm* and *d=2 mm*. Considering both gain and return loss the best performance of the DIFA is obtained when *l=14 mm*. Now maintaining the length *l=14 mm* we continue our advance analysis on the tap distance *t* as shown in Figure 7 and we observe that when *t=6 mm* the DIFA provides more negative return loss at the application bands than other values. Figure 8 shows the effects of width *w* on return loss when the tap distance *t=6 mm* and length *l=14 mm*. From Figure 8 we observe that the DIFA provide best return loss performance when *w=4 mm*. From overall analysis we see that double IFA (DIFA) provides best performance for the desired applications. The optimized dimensions of the proposed DIFA are listed in Table I.

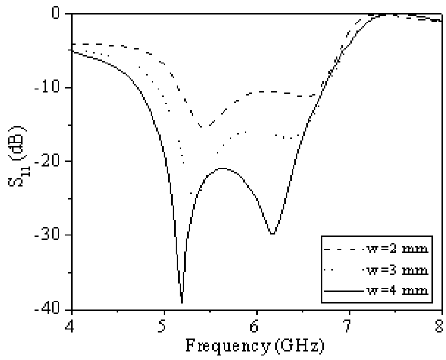


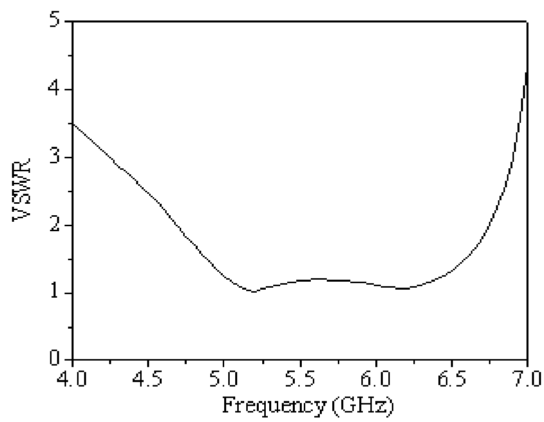
Figure 8. Return loss as a function of frequency with different value of width *w* of the DIFA of Figure 2 when *t=6 mm* and *l=14 mm*.

TABLE I.
OPTIMIZED DIMENSIONS OF THE PROPOSED ANTENNA

Antenna Name	Antenna Parameters	Values (mm)	Dimension (mm^2)
DIFA	*l*	14	9×20
	t	6	
	h	4	
	h_1	3	
	d	2	
	w	4	
	s	1	

III. Numerical Simulation Results

The proposed antenna is constructed and numerically analyzed using MoM's. The proposed DIFA has the return loss appreciable than the commonly required 10 dB level. Figure 9 (a) and (b) shows the variation of voltage standing wave ratio (VSWR) and return loss respectively. The DIFA provides a wide impedance bandwidth of 2.1 GHz (4675 MHz~6775 MHz) which fully covers the 5.2, 5.5 and 5.8 GHz bands and the peak value of return loss are -39.0732, -21.6220 and -21.7404 dB respectively. The value of VSWR of DIFA varies from 1.0412 to 1.1960 within the operating band and obtained result indicates that the variation of VSWR is very low and it is near to 1 as shown in Figure 9 (a).



(a)

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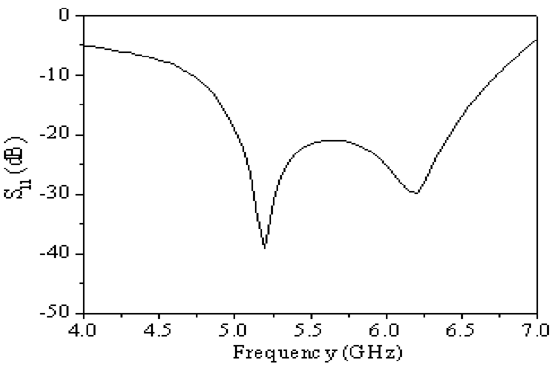
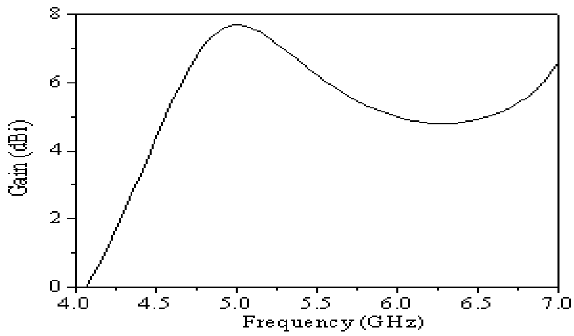
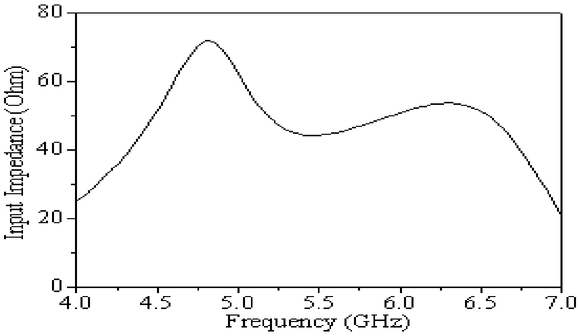


(b)

Figure 9. (a) VSWR and (b) Return loss variation of DIFA with frequency.



(a)



(b)

Figure 10. (a) Total gain and (b) Impedance variation of DIFA with frequency.

Figure 10 (a) shows the gain of DIFA. The peak gains of DIFA is 7.45, 7.01 and 5.50 dBi with less than 0.7, 1.5 and 0.3 dBi gain variation within the 10 dB return loss bandwidth at 5.2, 5.5 and 5.8 GHz band respectively, which indicates that the antenna has stable gain within the every separate operating bandwidth. Figure 10 (b) represents the antenna input impedance variation and Figure 11 represents the antenna phase shift causes due the impedance mismatch as a function of frequency. From the obtained results, the input impedance of DIFA is 49.16764, 44.27612 and 47.62756 &! at 5.2, 5.5 and 5.8 GHz and the impedance varies within 51.66177 to 44.27612 &! throughout the operating bands that is the input impedance of the proposed antenna is near about 50 &!. Also, from the simulation study, the antenna offers a phase shift of -0.83689^0, 6.47264^0 and 8.93735^0 respectively. So phase shift of DIFA closer to 0^0 all over the antenna bandwidth except at the end of 5.5 GHz and start of 5.8 GHz band, where phase shift closer to 9^0. A comparison in gains between the proposed and reference antennas are listed in Table II. In overall considerations, DIFA is much better than all other antennas. Figure 12 to 14 shows the normalized radiation patterns of DIFA at 5.2, 5.5 and 5.8 GHz bands respectively. Normalized radiation patterns for three resonant frequencies are shown as: total gain in vertical (YZ/XZ plane) and horizontal plane (XY plane). The antenna's normalized total radiation in vertical and horizontal plane is almost omnidirectional at the 5.2/5.8 GHz WLAN and 5.5 GHz WiMAX operating frequency.

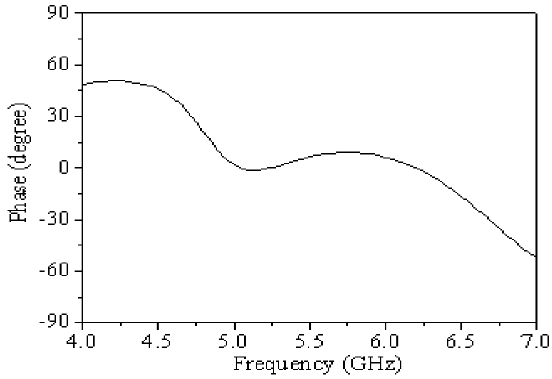
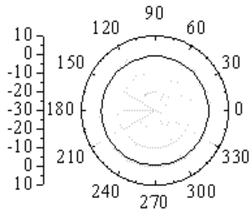
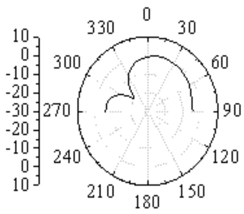


Figure 11. Phase variation of DIFA with frequency.

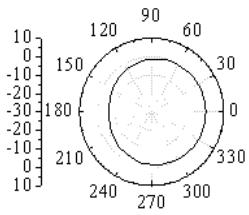


(a)

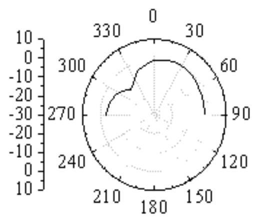


(b)

Figure 12. Radiation pattern (normalized) (a) Total gain in horizontal (XY) plane and (b) total gain in vertical (YZ/ XZ) plane of DIFA at 5.2 GHz.



(a)



(b)

Figure 13. Radiation pattern (normalized) (a) Total gain in horizontal (XY) plane and (b) total gain in vertical (YZ/XZ) of DIFA at 5.5 GHz.

A compact monopole, composite monopole, planar inverted-F, triangle-shaped monopole, printed monopole, hybrid monopole/slot chip, printed quasi-self-complementary structure, spider-shaped dipole, T-shaped monopole, planar two-strip monopole, printed T-shaped monopole , printed double-T monopole and slot antenna [1-13] have been proposed for WLAN or WiMAX or both applications suffers from gain limitations. But from Table II the our proposed antenna has much improved gain and stable gain variation within the antenna bandwidth then the antennas proposed earlier.

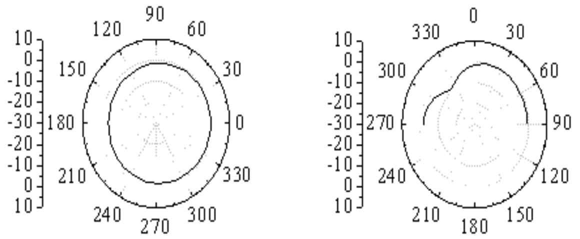


Figure 14. Radiation pattern (normalized) (a) Total gain in horizontal (XY) plane and (b) total gain in vertical (YZ/XZ) plane of DIFA at 5.8 GHz.

TABLE II.
GAIN COMPARISON BETWEEN THE PROPOSED AND REFERENCE ANTENNAS

Antenna	Peak Gain (dBi)		
	5.2 GHz WLAN	5.5 GHz WiMAX	5.8 GHz WLAN
DIFA (Proposed)	7.45	7.01	5.50
Compact monopole [1]	–	–	2.105
Composite monopole [2]	4.6–5.3		
Planar inverted-F [3]	2.3	4.4	
Triangle-shaped monopole [4]	3.59	–	3.05
Printed monopole [5]	4.0		
Hybrid monopole/slot chip [6]	2.7–3.8		
Printed quasi-self-complementary structure [7]	3.3–4.0	–	3.2–3.8
Spider-Shaped Printed Dipole [8]	4.6		
T-shaped monopole [9]	–	1.0	
Planar two-strip monopole [10]	3.6–4.3		
Printed T-shaped monopole [11]	3.5	–	3.5
Double-T monopole [12]	0.8–1.5	–	–
Slot antenna [13]	-1.58 – 0.78		

CONCLUSIONS

A wideband double IFA for 5.2/5.8 GHz WLAN and 5.5 GHz WiMAX applications is proposed by means of numerical simulations. The proposed antenna is of compact size with bandwidths of 2.1 GHz (4675 MHz~6775 MHz). Moreover the peak gain of the antenna is incredibly high and the gain variation of the antenna within the return loss bandwidth are lower means the antenna provides stable gain for the required applications. From the analysis antenna gain, radiation pattern, return loss and input impedance is suitable for the specified applications then the antennas proposed earlier. Due to the compactness of the antenna, it is promising to be embedded within the different portable devices employing 5.2/5.8 GHz WLAN and 5.5 GHz WiMAX applications.

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